PRESIDENTIAL ADDRESS

SOME PRESENT-DAY ASPECTS OF MYCOLOGY

BY

F. T. BROOKS, M.A., F.L.S.

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SOME PRESENT-DAY ASPECTS OF MYCOLOGY.

The British Mycological Society may legitimately congratulate itself upon the impetus recently given to the study of mycology in this country, for its members have been largely responsible for the increased attention now given to this branch of botany. Under the able and energetic direction of the general officers, the Society has greatly increased its membership and has extended its activities with success, so that it is now a very vigorous body, meeting frequently in London or elsewhere, throughout the year. I am assured also that the efforts of the Society to assist in the mycological education of botanical students, especially in the field, are warmly appreciated. Another activity which has been supported by the Society is the establishment of a collection of pure cultures of fungi in the National Collection of Type Cultures at the Lister Institute, which, it may be hoped, will in time become the premier collection of its kind in the world. The recent establishment of the Imperial Bureau of Mycology under the directorship of Dr E. J. Butler is another indication of the importance which our subject has assumed in the Dominions and Colonies as well as at home. The publication by the Bureau of the "Review of Applied Mycology" is an event of special importance, and all mycologists are grateful for its appearance.

Mycology is a subject of wide scope, for fungi are aggressive organisms and play a by no means insignificant part in the economy of nature. Our branch of Botany has intimate connections with Cytology, Genetics, Protozoology, Medicine, Biochemistry, Plant Physiology and Plant Pathology. Indeed so close is the association between Mycology and Plant Pathology that the two are often identified in the minds of the scientific public, and although there are certain differences

between them, it is often impossible to say where mycology ends and plant pathology begins. A large part of the credit attributable to the recent progress in plant pathology, must undoubtedly be given to mycologists. During the past few years there has been a considerable influx of plant pathologists into the Society, and I trust it will ever be the aim of the Society to extend a warm welcome to all those scientific workers whose investigations require a knowledge of the life-habits of fungi for their solution.

Members of the Society have also recently been active in the publication of books upon fungi and allied organisms, and the reproach that there were no good modern British books on mycology is no longer valid. It is a pleasure to refer to the literary activity of several of our members: Miss Lorrain Smith's book on Lichens is the culmination of a life-study of this group, and will for many years be the standard work of reference upon these strange plants. Professor Dame Helen Gwynne-Vaughan's book on Fungi fills a much-needed want, and is a mine of information upon some of the most interesting groups. Within the last few months there has also appeared under the auspices of the British Mycological Society Mr Carleton Rea's book on "British Basidiomycetae." It must be a particular pleasure to Mr Rea, as it is to all of the members of the Society to see his monumental work in print, which will be a lasting tribute to his indefatigable zeal and skill in the study of the higher fungi. Mr Ramsbottom has revised the guide to the larger fungi in the British Museum and has provided therein a tale of the exciting adventures of toadstools and cup fungi which will not soon be exhausted. Finally Professor Buller has a second volume of his researches on Fungi on the point of publication, and we are all looking forward to reading the story of the new discoveries of the one who may be well called, without irreverence, the mycological magician. To each one of these authors the British Mycological Society will wish to offer its hearty congratulations.

In all these respects, members of the British Mycological Society have been active in promoting the study of mycology, and the liveliness in this subject which has arisen in consequence, augurs well for the future both of mycology and of our Society.

In the membership of our Society, there has been perhaps a greater influx of professional than amateur workers, and it may perhaps be feared by some that the interests of the amateurs may come to be overlooked. Speaking as a professional worker I trust that will never be. British mycology was fathered by an amateur, the Rev. M. J. Berkeley, and this Society was largely founded also by amateurs including Mr Cheesman and

Mr Carleton Rea, the latter of whom has been its guardian angel ever since. May I add that many of us academic workers owe a deep debt of gratitude to workers like Mr Rea who of their never-failing kindness help us persistently out of our systematic difficulties? I feel confident therefore that the mycological work of amateurs will be as warmly welcome in the future as in the past. The amateur is the salt of the earth, for it is he alone who is impelled to work by the love that is in him. Science is in danger of becoming over-professionalised, and it is only the spirit of the amateur that can preserve the freshness of outlook essential to the intellectual health of the professional investigator. At the last annual foray, the discussion initiated by Dr Butler indicated many of the ways in which amateur workers could be of assistance in promoting the study of fungi, and with the co-operation of both kinds of workers, British mycology has a rich harvest before it.

The Origin and Phylogeny of the Fungi.

I propose now to say a few words about the origin and phylogeny of the fungi. I know that in discussing this subject I am treading on dangerous ground, but I trust you will bear with me in my heterodoxy. I have just come from the meeting of the British Association for the Advancement of Science at Hull where there has been considerable discussion on the subject of Evolution. Anent this discussion Dr D. H. Scott made the remark that the day had passed when biologists thought they knew a great deal about the phylogeny of organisms; in his striking phrase, "phylogeny eludes us." This does not mean that nothing is known about the race-history of the main groups of animals and plants, but that we know far less than was thought only a few years ago. Notwithstanding this change in outlook there is still prevalent in the teaching of elementary botany a view of the origin and development of the fungi, to the exclusion of other possibilities, which I venture to combat. Besides, it is well occasionally to take a broad survey of the group of organisms with which we are dealing, for like all other students of detail, we are sometimes apt to miss the wood for the trees. The fungi are a remarkable group of organisms of which we, as mycologists, are rightly proud, but their unique characters are often overlooked, and many botanists look upon them as a race of degenerate organisms, poor anaemic creatures that have lost the power to photosynthesise. Let us examine this standpoint somewhat critically. Nowhere else in the plant kingdom is there an immense group which is looked upon as having been derived from green organisms by the loss of

chlorophyll. Where saprophytic or parasitic forms occur amongst green plants, their numbers are limited and diversity restricted, as if the loss of pigment and holophytic mode of nutrition had checked their evolutionary impetus. Thus the families of parasitic flowering plants, Orobanchaceae and Rafflesiaceae contain comparatively few genera and species, as if their undoubted degeneracy had brought the inevitable penalty in its train. Likewise the parasitic algae are few in number of species and infrequent in occurrence, pointing to the same truth that loss of a fundamental character leads inevitably to grave handicap in the struggle for existence. The fungi, on the other hand, rival the flowering plants themselves in number of species and diversity of form, and it is altogether against the laws of probability that they have been derived from such groups as the Green and Red Algae by the loss of pigment and development of a saprophytic or parasitic mode of nutrition. Thanks to the researches of Kidston and Lang* we now know that the fungi are at least as old as the Devonian rocks, and it is likely that they date back to that far distant time when the chief groups of lower organisms were becoming differentiated after the dawn of life in the primitive ocean. With their infinite variety, the fungi must have possessed some of that evolutionary driving power which was inherent in the organisms that gave rise to the dominant groups of plants and animals. It has been suggested by Church† that the growth-forms of the fungi, including the lichens, are essentially those of marine algae, and he apparently denies to the group any really independent power of form development. For instance he states‡ that "a higher fungus of the land is in short a skinned seaweed, implying a more or less elaborated algal growth-form, in which in the death and decay of the older metabolic and autotrophic surface layers, the exposed internal heterotrophic tissues continue their heterotrophic existence at the expense of the soluble carbohydrates of the standing and non-aerated medium." Where for instance amongst the algae will be found the growth-forms of *Xylaria*, *Polyporus squamosus*, the common mushroom, or finally of the elegant *Dictyophoras* of the Gasteromycetes? It must not be forgotten that in the higher fungi the conspicuous part is essentially a spore-producing structure which cannot be directly compared with the somatic equipment of the algae.

Church's view is that the fungi have been derived from transmigrant algae by the loss of chlorophyll, such algae being

* Kidston, R. and Lang, W. H. On Old Red Sandstone Plants showing structure, etc. Part v. Trans. Roy. Soc. Edin. LII, p. 855 (1921).

† Journal of Botany, p. 41 (1921).

‡ Church, A. H., Thalassiophyta, p. 59, etc., Oxford (1919).

of a much more generalised type than marine forms at present existing. This is an interesting speculation, but it is not more than a speculation, and even if an agnostic attitude be adopted in regard to it, most mycologists will combat the idea that the fungi, thus derived, possess little or no novelty in form-development.

Although Church's view that fungi have arisen from trans-migrant algae is unsatisfying, even more problematical is the outlook, still prevalent among botanists, that the fungi have been derived from algal forms somewhat similar to existing types of Green and Red Algae. This is a reflection of the views of Pringsheim, de Bary, and Sachs, especially of the last named. It may be remembered that Pringsheim actually placed *Saprolegnia* amongst the green algae, as a colourless form. Since the lifetime of these botanists, however, further research has thrown a flood of new light upon the fungi, which makes much more problematical the correctness of their views. It is a commonplace of botanical lecturers to compare *Pythium* with *Vaucheria*, and *Mucor* with *Spirogyra*, and the comparison is not infrequently accompanied by more than a suggestion that the forms may be phylogenetically connected. Again, the Ascomycetes and the Rust Fungi are commonly connected with the Red Algae, in the main, apparently on account of the presence of trichogynes and spermatia. In my opinion the resemblances between these groups of algae and fungi are entirely superficial, and are of no phylogenetic significance whatever. If the comparison is pressed for instance between *Pythium* and *Vaucheria*, enormous differences are found between the two forms; for instance the mode of germination of the zygote, a character probably of considerable ancestral importance, is different, and the characters of the ciliated cells are so diverse that a phylogenetic connection seems out of the question*. It is even more difficult to conceive of a phylogenetic comparison being drawn between *Mucor* and *Spirogyra*, and the sooner such is relegated to the limbo of forgotten things, the better for botanical clarity of vision. As between the Ascomycetes and the Uredineae on the one hand, and the Red Algae on the other, the comparison is usually of a more delicate nature, but it seems equally fallacious. The comparison between the trichogynes of the respective groups can hardly be taken seriously for there are great structural differences between them, while in sexuality

* Since delivering this address, Dr Butler has reminded me of his paper "On *Allomyces*, a new aquatic fungus" (Annals of Botany, xxv, p. 1123, (1911), in which this curious genus of the Leptomitaceae is compared with the algal genus *Dichotomosiphon*. Although the resemblance between the growth forms of these two genera is striking, the profound differences in reproduction appear to me to invalidate any phylogenetic connection between them.

and in nuclear cycle, the differences are profound. Again, the argument is often advanced that in certain groups of existing algae, the phenomenon of parasitism exists, accompanied by the partial or total loss of chlorophyll, as in *Harveyella* and *Chroolepus*, and that this illustrates the way in which fungi have arisen. Although these forms have wholly or partly lost their chlorophyll they still reproduce in a purely algal manner and show no approach to a fungoid nature. Now it is a general belief, and probably a correct one, that parasitism in the fungi is a more recent development than saprophytism. Saprophytic algae are exceedingly rare and show even less approach to mycelial growth than do the parasitic forms. Saprophytism and parasitism in the algae at the present day are exactly the same phenomena as the occasional adoption of these modes of nutrition in other holophytic groups, and have no significance as regards the origin of the fungi, the peculiarities of which must be sought elsewhere. If the fungi had been derived from algae by the loss of chlorophyll, one would expect to find in certain fungal forms at any rate, traces of the same type of carbohydrate metabolism as that existing in the algae. Such in point of fact does not occur, and an entirely different set of carbohydrates is found in the fungi.

The almost universal hyphal development of the fungi is sometimes compared with the filamentous nature of many algae. In most groups of algae, the filamentous types pass over into more complex forms in which longitudinal divisions of the cells occur, and, in the higher forms of algae, tissues are present closely similar in character to those of terrestrial green plants. On the other hand, even in the most highly developed fungi, longitudinal divisions of the cells are almost unknown, and the tissue systems are of a type unique in the plant world. Here again there is a great gulf fixed between the algae and the fungi. If the two groups had been phylogenetically connected, the higher fungi would probably have exhibited some of the types of cell aggregation prevalent in the holophytic algae. The hyphal development of the fungi can be looked upon as a pronounced type of cell expression, potentially present in all living cells, which has been developed to an extreme degree in correlation with peculiar modes of nutrition. Whenever a somatic part of an organism with an essentially absorbent function is embedded in a nutritive medium, be that dead or alive, there is a tendency to a hypha-like type of growth, as, for example, in the rhizoids and root hairs of green terrestrial plants. Again the growth of a pollen tube in the tissues of the style is essentially hypha-like, and the vegetative body of the Rafflesiaceae, a parasitic family of flowering plants, is practically a mycelium. Even in animal

cells, this tendency to hypha-like proliferation in response to a peculiar environment is of common occurrence, as for example in cartilage tissues grown aseptically under artificial conditions. As regards the latter, the parallel is so close to the growth of a fungus mycelium that a friend who was investigating the growth of animal tissues under cultural conditions, at first thought that his cultures had become contaminated by a fungus; the hypha-like threads were in fact nothing but proliferating cartilage cells. Thus the mycelial character of the vegetative body of most fungi must be looked upon as a type of cell development elaborated in connection with special nutritive needs, and not in any way as being mainly the expression of an algal ancestry.

Another marked difference between the fungi and the algae, and indeed all other groups of green plants, lies in the chemical composition of the cell membranes. It has long been known that the cell walls of fungi differ chemically from the cellulose which is the chief constituent of the cell walls of other plants. At first the main constituent of hyphal walls was called "fungus-cellulose," but more recently it has been shown that this substance contains nitrogen whereas true cellulose does not, so that it differs markedly. The main constituent of fungal walls resembles in many ways the chitin of animal cells. Recent investigations tend to emphasise the phylogenetic significance of the chemical constitution of cell membranes, and it seems clear that if the fungi had been derived from the algae there would be closer approximation in the characters of the membranes. For instance, the chemical differences between the cell walls of *Pythium* and *Vaucheria* make it certain that an immense gap lies between them, apart from all other considerations. While mentioning chemical differences between fungi and other plants, it may be pointed out that many fungus pigments are highly peculiar, especially those of the lichens. On the other hand most of the pigments of green plants show close relationships to one another.

With these profound and fundamental differences between the fungi and the algae it may not be unprofitable to consider in some detail the view which has been put forward by Dangeard* and others that the origin of the fungi is to be sought in unicellular protist organisms. Dangeard has had a unique experience as an investigator of the lower forms of life, both plant and animal, and his views are entitled to most serious consideration. In the main I am in harmony with him although I cannot agree with some of his deductions. At the bottom

* Dangeard, P. A., Les ancêtres des champignons supérieurs. Le Botaniste, IX, p. 157 (1903).

of the plant and the animal kingdoms there are large numbers of forms which in some respects show plant characteristics and in others, animal characteristics, *i.e.* are intermediate between the plant and animal kingdoms, as well as innumerable other types which, though predominantly plant or animal-like, can scarcely be regarded as definitely one or the other. The Flagellata, the Mycetozoa, and the Bacteria are groups of this class. Some of the Flagellata are intermediate in character between plants and animals, while others possess almost exclusively animal characteristics. The Mycetozoa are predominantly animal-like in one phase of their existence, and plant-like at another, while the Bacteria are chiefly plant-like throughout their development. Whatever view is taken of the origin of protoplasm, *i.e.* of life on this planet, it is clear, from what is known of evolutionary processes, that at the dawn of life the forms were probably very few, perhaps only one, possessing a mode or modes of nutrition conceivably different from those of the great majority of plants and animals of the present day. Certain forms of bacteria obtain their essential supplies of nitrogen and carbon even now by ways which are neither like those of typical plants nor animals. It is possible, therefore, that the earliest forms of life were generalised types, neither definitely plants nor animals, perhaps possessing peculiar prototrophic modes of nutrition. I mention this possibility as it is sometimes postulated that plant forms must have preceded the evolution of animal organisms. Now it is likely that long before organisms possessing tissue systems had become differentiated, the chief groups of the Protista had come into existence, so that there was no lack of organisms of a saprophytic mode of nutrition available in the sea at the time when the larger seaweeds were being evolved. It is less difficult to conceive of the direct evolution of such unicellular types into forms with hyphae as a response to continued possibilities of existence in vegetable and animal debris, than it is to suppose that the fungi have in the main been evolved directly either from transmigrant algae, or from Green and Red algae somewhat similar to existing types. The fungi undoubtedly possess some of the initial, evolutionary impetus characteristic of all the primary groups of living organisms, which they hold by virtue of an early differentiation from protist organisms.

One of the difficulties encountered by those who derive the fungi from the algae is to account for the Chytridiineae from an algal ancestry. There are few algae to which these peculiar fungi can be even remotely associated, and the group contains several families of great diversity. The simplest types are approximately spherical with no attempt at proliferation, but other forms

show the initiation of hyphal development. Dangeard*, Atkinson† and others who have worked much on the lower forms of life have suggested a connection between the Chytridiineae and certain groups of the protozoa, and there are many points of contact between the two, both as regards cytology and ontogenetic development. Wager‡ called attention to certain protozoan similarities in his investigation of *Polyphagus Euglenae*, and the recent account of the cytology of *Synchytrium endobioticum* by Curtis§ also shows points of resemblance. The absence of cell membranes in many Protozoa is often held to discount the connection between fungi and protist organisms, but large numbers of Protozoa possess well-defined membranes by no means exclusively in the encysted condition, while some fungi are devoid of walls in certain phases of their existence. Thus some of the Foraminifera possess chitinous membranes, and many Radiolarians, Heliozoans and Ciliates have well-defined walls, while in the lower fungi certain stages of the life-cycle are devoid of membranes, and in *Synchytrium endobioticum* the organism is entirely devoid of a wall until a somewhat late stage in development.

Apart from the confusion that formerly existed between certain Chytridiineae and Monads, some organisms are with difficulty classed in the Protozoa or the Chytridiineae, *e.g. Rhinosporidium*‖ in the Haplosporidia, just as there are some types, *e.g. Sappinia pedata*, which may be a connecting link between the Protozoa and the Mycetozoa. Again, the Chytridiineae show marked differences from one another as regards sexuality, but all sexual processes within the group are of a relatively primitive nature and some of these are closely similar to processes of fusion in the Protozoa. The sexuality of the fungi is often looked upon as a residuum, as it were, of the sexual processes existing in the algae. It seems much more reasonable to conclude that like other groups of organisms, both in the plant and in the animal kingdoms, they have initiated their own sexual processes which have been evolved along unique lines in correlation with peculiar environmental conditions. With the development of special methods of reproduction, with the initiation of sexuality, and with the beginnings of hyphal formation, we may see justification for including, as does

* Loc. cit.

† Atkinson, G. F., Some problems in the evolution of the lower fungi. Ann. Myc. VII, p. 441 (1909).

‡ Wager, H., The life-history and cytology of *Polyphagus Euglenae*. Ann. Bot. XXVII, p. 173 (1913).

§ Curtis, K. M., The life-history and cytology of *Synchytrium endobioticum* (Schilb.) Perc. etc. Phil. Trans. Roy. Soc. CCX B, p. 409 (1921).

‖ Prof. J. H. Ashworth in his recent paper on *Rhinosporidium Seeberi* refers this genus to the Chytridiineae (Trans. Roy. Soc. Edin. LIII, p. 301 (1923)).

Lotsy* the Chytridiineae in a primitive group the Archimycetes from which other groups of fungi may be held to have arisen.

In certain members of the Oomycetes and Zygomycetes, the atypical development of the hyphae must have struck everyone. With forms like *Phytophthora* in particular, the hyphae often become vesicular, even under normal conditions, and appear strangely unlike hyphae of the higher fungi. In a new genus (*Caeolomomyces*) recently described by Keilin†, which has a more marked mycelial development than in other Chytridiineae although in most respects it appears to belong to this group, the hyphae are particularly wide and irregularly swollen, and show an intermediate condition between a vesicular and a hyphal mode of development. These aberrant hyphal forms may be the expression of an ancestry from non-hyphal types, such as protozoal or other protist organisms.

There are forms also which are classed with difficulty either as bacteria or as fungi, as *e.g.* species of *Actinomyces* and *Streptothrix*, and the possibility of connection between the higher bacteria and the fungi must not be overlooked, although it is more likely that the relationship is not of a direct nature.

The outlook of the writer upon the fungi is therefore that it is an enormous group of organisms of extreme age and probably of protist origin, which has developed upon independent lines, and which shows the same kind of differences between its constituent divisions as do other large phyla of plants and animals. Theories of evolution are again in the melting pot, and although the facts of evolution are not in dispute, there seems to be more uncertainty than ever as to the manner in which it has been brought about. By some authorities the fungi are considered to be of polyphyletic origin and some who hold to the protist or Chlorophycean origin of the lower fungi, deny this to the higher fungi, deriving the latter from the Rhodophyceae. However little is known about the origin of the fungi, we are equally ignorant of their phylogeny. But if a totally different origin for the lower and the higher fungi be postulated there is evidently a great gap between the Phycomycetes and the Ascomycetes, which is unbridgeable. Now there are sufficient similarities between the Ascomycetes and the Phycomycetes to nullify the hypothesis that there is no conceivable connection between them. By no great stretch of the imagination a form such as *Pyronema confluens* may conceivably be derived from *Albugo Bliti*, although I do not wish to imply that this may actually have happened. Although Brefeld's old group of the Hemiascomycetes will not stand the

* Lotsy, J. P., Vorträge über botanische Stammesgeschichte, Jena (1907).

† Keilin, D., On a new type of fungus: *Caeolomomyces stegomyiae* n. g., n. sp., etc. Parasitology, XIII, p. 225 (1921).

test of enquiry, there are undoubtedly forms such as *Dipodascus* which tend to link the Ascomycetes with the lower fungi. As regards the difference between the non-septate hyphae of the Phycomycetes and the septate hyphae of the Eumycetes, this is often unduly emphasised. Many Phycomycetes are not infrequently septate, *e.g. Spinellus* in the Mucorineae, especially when the hyphae are old, while in the higher fungi, hyphae frequently remain unseptate during active growth. I would suggest rather that the Ascomycetes were evolved from the lower fungi at some far distant time, long before the present forms of the Phycomycetes existed. The Ascomycetes are clearly of one origin, for the structure of the ascus is so uniform throughout the group that it is inconceivable it could have arisen polyphyletically. Church homologises the ascus with the spore mother cells or tetrasporangia of marine algae. The ascus is clearly a spore mother cell, but to grant this does not imply the phylogenetic connection which Church appears to indicate. Wherever sexuality occurs, reduction in the number of chromosomes must necessarily follow, this being most readily achieved by nuclear divisions in a mother cell. Just as the fungi are held to have developed along their own sexual lines, so the spore mother cells or asci in the Ascomycetes, are the necessary counterpart of sexual processes. The peculiar development of ascogenous hyphae with their ultimate formation of asci, is a means of enormously increasing the spore output in relation to sexuality and in correlation with special modes of dispersal and nutrition involving tremendous wastage of reproductive units. Again, the basidium of the Basidiomycetes is often held to have no relationship with the ascus. On the other hand the basidium is essentially the same cytologically as the ascus. In both there is a fusion of nuclei followed by a reduction in the number of chromosomes. There are usually three nuclear divisions in the ascus and two in the basidium, but Juel* has recently demonstrated the existence of more than two divisions in the spore mother cells of many Basidiomycetes. In my opinion the basidium can be held to have been derived from the ascus in correlation with a different type of spore discharge. Buller† has shown that the spores of many Basidiomycetes are violently ejected from the sterigmata. Now whereas in most Ascomycetes each ascus ejects all its spores simultaneously, in the Basidiomycetes each spore is discharged separately from the basidium. If the process of spore formation of a basidium

* Juel, H. O., Cytologische Pilzstudien, I. Die Basidien der Cantharellus, Craterellus, und Clavaria. Nov. Act. Reg. Soc. Sc. Upsala, ser. IV, iv, no. 6 (1916).

† Buller, A. H. R., Researches on Fungi, II. Longmans and Co., London (1922).

is considered in detail, although the differences between basidiospore and ascospore formation are considerable, these are not so profound as might be thought at first sight. The divergence in method of spore formation and spore discharge between the Ascomycetes and the Basidiomycetes is correlated with diversities in style of architecture, but in both groups the spore mother cells are fundamentally the same and are often multiplied indefinitely to provide for an enormous spore output.

The Uredineae and Ustilagineae are peculiar groups of obligate or semi-obligate parasites which show no close relationship with other Basidiomycetes, but which undoubtedly fall within this category. The Uredineae in particular exhibit considerable resemblance to the Ascomycetes. No one who has worked on the cytology of such forms as *Gnomonia*, *Polystigma*, or the lichen fungi can fail to be impressed by their likeness in certain respects to rust fungi. The spermogonia of both and certain features in the development of aecidia and perithecia show a marked resemblance, which may point to ancestry from a common stock or may be of even greater phylogenetic significance. The similarity between certain Ascomycetes and the rust fungi was commented upon by de Bary* many years ago, and I ventured to call attention to it in a paper on *Gnomonia erythrostoma* published in 1910†. The gap between the Basidiomycetes and the Ascomycetes is not unbridgeable, and a common origin for both groups is indicated. The divergence between them is of long standing, and may date back to the time when they, together with early forms of the Phycomycetes, began to be evolved from the first organisms of a definitely fungoid nature. It may be mentioned here in passing that there is much to be said for separating the Smut and the Rust Fungi from all other basidia-producing fungi, and constituting them a group of equal rank with the Ascomycetes and the remainder of the Basidiomycetes.

It is maintained, therefore, that the fungi are a monophyletic group, established in far-distant times from protist organisms, which have evolved along their own lines just like any other large group of plants or animals. In the past a polyphyletic origin for many groups of organisms including fungi has been advanced, but the present trend of opinion is in favour of attributing each phylum to a common ancestry, notwithstanding the existence of great discontinuity of type within the phylum. It is admitted that it is particularly difficult to trace relation-

* de Bary, A., Comparative morphology and biology of the fungi, mycetozoa and bacteria. English translation (1887).

† Brooks, F. T., The Development of *Gnomonia erythrostoma* Pers. Ann. Bot. XXIV, p. 585 (1910).

ships amongst the fungi, largely because their vegetative characters, being almost valueless as a criterion of relationship, cannot be used as in other plants and animals, to supplement comparisons of reproductive organs.

All workers on evolution have been struck by the marked discontinuity of character both between different groups of organisms and also within each group. This discontinuity is one of the most marked features of living organisms, and it is just as much exemplified in the fungi as in other groups of organisms, but there is no more reason for supposing that the liverworts have arisen from several different sources than that the fungi have been so derived.

Thus as against the opinion that the fungi are organisms which have come directly from the algae by the loss of photosynthetic power, arguments have been advanced in favour of the view that the forms from which they came never possessed this power. Organisms which lose such an important character as chorophyll are invariably strictly limited in their power of development, whereas no group of organisms shows more diversity of species than do the fungi. The fungi, possessing some of the original impetus of primitive life, have evolved along their own lines, and have achieved entirely novel types of reproductive mechanism. To elaborate a new style of architecture is not the mark of a decadent civilisation, and the fungi having achieved so much that is unique in the plant kingdom cannot be looked upon as a degenerate race. When the fungi are spoken of as an insignificant race with no power of independent development, I am reminded of a book I read in boyhood, namely, Jules Verne's "Journey to the centre of the earth." It will be remembered that, with the novelist's imagination, he represents the voyagers in the interior of the earth as having to traverse a gigantic mushroom forest where fungi had achieved an arborescent habit of growth. Jules Verne at any rate was alive to the possibilities of fungi, and his outlook is to be preferred to that which holds the group to be devoid of initiation and crippled by degeneracy.

The Relation of Mycology to Plant Pathology.

As most plant diseases are caused by fungi, the relation of mycology to plant pathology is clearly of great importance. An accurate knowledge of pathogenic fungi is indispensable to anyone who attempts to deal with the more general aspects of disease in plants or with its control. Mycology is one of the foundation stones of plant pathology, and indeed Berkeley and de Bary, both eminent mycologists, were the real founders of

the serious study of disease in plants. Just as plant physiology is dependent in part upon systematic botany, so is a knowledge of the fungoid diseases of plants dependent upon systematic mycology for accurate treatment. Whenever one branch of knowledge is intimately connected with another there is usually a mutual reaction of the one upon the other and I trust that plant pathology will be not without influence on systematic mycology. Persons who investigate plant diseases often encounter difficulties in the identification of the pathogen which can only be solved with the aid of the systematic mycologist, and I should like to acknowledge here the great assistance received in my own work from systematic mycologists. But the plant pathologist is often avaricious in his desire for information, and sometimes the particular knowledge he requires from the systematic mycologist is not at present available. The plant pathologist is accustomed to growing pathogenic fungi in pure culture whenever possible, where their behaviour can be followed under carefully controlled conditions. In this way he gets an idea of the range of variability of a species which is often at variance with its formal diagnosis and with that of allied forms. Thus the innumerable forms of *Cladosporium* which have been described in systematic works are meaningless to the plant pathologist, for he finds by experience that they can all be grouped around a few types which are the real units. It is clear that species must be diagnosed upon the basis of characters shown on natural substrata, but the time has come when these descriptions should be supplemented by an accurate account of their behaviour upon standard media under controlled conditions wherever the forms can be readily cultivated. To diverge for a moment; this mode of treatment has become an urgent necessity for the moulds as shown by Thom in the genus *Penicillium* and by Lendner in the Mucorineae, and the time can be foreseen when biochemical reactions will be of fundamental importance in differentiating such types. It may be remarked that it is merely a platitude to urge supplementary descriptions of the species as grown in artificial culture, but it is important to reiterate this necessity, for few systematic mycologists yet realise its significance.

Again, with parasitic genera like *Ramularia, Ovularia, Gloeosporium,* etc., the diagnosis of species is unsatisfactory to the worker on plant diseases. The chances are that if either of these forms is found on a new host, a new species will be created without adequate comparison with existing species. Shear and Wood* have shown that many species of *Gloeosporium* hitherto

* Shear, C. L. and Wood, A. K., Studies of fungous parasites belonging to the genus *Glomerella*. U.S. Dept. Agric., Bureau of Plant Industry, Bull. 252 (1913).

considered distinct are really identical, and it is unquestionable that there should also be a considerable elimination of species in other genera. In parasitic genera of this kind it is only by cross inoculations that proper host relationships can be discovered, so that it is urgent here for the systematist either to become a pathologist for the time being or to work in close co-operation with one. Species diagnosis must at present be primarily based upon structural characters, and however useful physiological characters may be for the separation of distinct strains, physiological differences alone cannot yet be taken as adequate criteria for species differentiation. In many pathogenic fungi there is exhibited the phenomenon of specialised parasitism, *i.e.* the existence of a number of forms differing in host relationships but either only slightly or not at all in structure, within the limits of a single species as ordinarily understood. This phenomenon is particularly well shown in *Puccinia graminis* which comprises many forms of distinct physiological relationship such as the variety *Tritici* confined almost entirely to wheat, and the variety *Secalis* upon rye, couch grass, and a few other grasses. Prof. Stakman of America has recently told me that some of these physiological varieties in America show slight structural differences, for example, in the dimensions of the uredospores and aecidiospores. If these structural differences were more considerable, there would be a strong claim for converting these specialised races into distinct species. In systematic work there will always exist, both the "lumper" and the "splitter," for in the main it is a matter of opinion as to what degree of difference constitutes specific differentiation. To the plant pathologist it does not much matter whether the species have been diagnosed by a "lumper" or a "splitter" as long as the basis of distinction is clearly set forth in language that he can understand. I must confess a preference for the methods of the "lumper" for, as stated in another place*, mycological systematy will become altogether too unwieldy if fungus species are set within too narrow limits.

Another difficulty encountered by the plant pathologist is that even the generic limitations hitherto imposed by systematists not infrequently break down in practice. In the Fungi Imperfecti in particular this difficulty is often met with, and it was pointed out a short time ago in dealing with certain tomato diseases* how the generic distinctions between *Phoma, Phyllosticta, Ascochyta* and *Diplodina* broke down. There cannot be any doubt but that many genera in this group are entirely artificial, and one looks forward to the time when some systema-

* Brooks, F. T. and Searle, G. O., An investigation of some tomato diseases. Trans. Brit. Myc. Soc. VII, p. 191 (1921).

tist will have the courage to eliminate many of these so-called genera, or establish a more adequate classification.

No branch of systematic botany should be divorced from the study of living plants, and just as those who classify flowering plants cannot but be assisted in their labours by following the work of geneticists and by watching the behaviour of the living plants under different environmental conditions, so, I think, it will be of advantage if systematic mycologists will actually grow certain groups of fungi under artificial conditions and will keep in intimate touch with plant pathologists. An instance of the lack of co-operation between fungal systematy and plant pathology is afforded by the separation of the species *Stereum rugosiusculum* from *Stereum purpureum* by Burt*. This distinction is supported by Rea in his "British Basidiomycetae." *Stereum purpureum* is the primary cause of silver-leaf disease of fruit trees in this country, and has hitherto been held to include the form *rugosiusculum* now separated by these authorities. Since Burt published his monograph on the genus *Stereum* I have examined many collections of this fungus from different substrata, and as far as investigation has proceeded, the chief distinction between the two species according to Burt, namely the presence of hymenial cystidia in *rugosiusculum* and not in *purpureum*, seems to be an inadequate criterion. In none of the specimens have the cystidia been so abundant as figured by Burt for *rugosiusculum*, but, apart from this, there has been every possible intergrade between forms possessing many hymenial cystidia and forms devoid of them. Indeed, within the limits of a single sporophore there are great differences in the distribution of these hymenial hairs. From the pathogenic standpoint I believe *S. rugosiusculum* and *S. purpureum* are one, and with all deference to Burt and to the author of "The British Basidiomycetae," I think doubt must remain as to whether *S. rugosiusculum* is a valid species until more adequate evidence is forthcoming as to its structural peculiarities. *S. purpureum* and *S. rugosiusculum* would probably never have been separated if the systematist had co-operated with a plant pathologist.

There are innumerable other relations between mycology and plant pathology, but only the briefest reference can be made to these. The day has passed when it was considered sufficient in investigating a plant disease of parasitic origin to determine the causative agent. Nowadays that is merely the beginning of a new series of investigations to elucidate precisely the conditions under which the pathogen can effect an entrance into the host, the exact mode of penetration, and the relationships

* Burt, E. A., The Thelephoraceae of North America, XII. Ann. Missouri Bot. Gard. VII, p. 127 (1920).

existing between the parasite and the surrounding tissues. Mycology therefore must be directed towards the study of the physiology of fungi as well as towards their morphology. Plant pathology is essentially abnormal plant physiology, in which a parasite is often the disturbing agency. Acting upon both host and parasite are environmental conditions which sometimes favour the one and sometimes the other. As Butler has indicated in his "Fungi and Disease in Plants" these external factors are often of critical importance in the establishment of disease. Several mycologists are now engaged upon an intensive physiological study of certain pathogenic fungi, and already at the hands of Brown, Wiltshire, and others, results of great importance have been obtained. For several years I have been engaged upon an intensive study of *Stereum purpureum*, and with the help of my colleagues, light is now being shed upon the exact manner in which this fungus causes infection of fruit trees. In the study of fungous diseases of plants, so many factors are involved that it is often supremely difficult to determine their relative importance, but it is certain that unless the physiology of the parasite be studied in detail, no considerable progress will be made in the fundamental elucidation of disease.

The Training of Mycologists and Plant Pathologists.

On this occasion it may perhaps be opportune to say a few words about the training of mycologists and plant pathologists. As regards training, it is hardly worth while to draw a distinction between mycology and plant pathology, for although there are important differences between the two classes of work in some spheres of activity, from the point of view of the men who are trained to occupy technical posts of this nature in various parts of the Empire, the work of most mycologists is essentially plant pathology, *i.e.* the investigation of plant diseases and their control. It is important to consider this matter carefully, because in distant parts of the Empire the mycologist is often a person of no mean importance; he has often been the first scientific officer to be sought by the cultivator on account of disease becoming a serious menace. If the mycologist sent out has been a suitable man and has been of assistance to the plant industry which invoked his aid, his success has often led to the formation of extensive agricultural and botanical departments which have become active centres of research and guidance in the many diverse branches of tropical agriculture.

In my opinion the mycologist must be essentially a botanist. Just as a doctor must be thoroughly familiar with all parts of

the human body so must the mycologist have a broad training in the general principles of botany, and apart from a special knowledge of fungi, his mind must be imbued with the importance of plant physiology. Without a clear insight into plant functions, a mycologist will often fail to see the most important aspects of disease in plants. With plant physiology of such great significance, the botanist who is going to become a mycologist must have received an adequate training in chemistry and physics, for without these foundations, the biologist in general and the mycologist in particular will be severely limited unless his work happens to be of an entirely morphological nature. By this emphasis upon the study of chemistry and physics even for the mycologist, I do not wish to minimise the importance of the study of natural history. Many of us, myself included, were led into scientific studies through the naturalist instinct, and for training in observation and discrimination there can be no finer introduction than the cultivation of this instinct. For the plant pathologist, the outlook of the naturalist is a splendid asset, but by itself it is not enough for the solution of the intricate problems of plant disease. Our young mycologist then should be a trained botanist with a physiological outlook and with the instinct of the naturalist perhaps in addition. He may now proceed to obtain a wider acquaintance with fungi and plant diseases, and may perhaps take short courses in bacteriology and entomology. Even then his training in my opinion will fall short of what is desirable. At this stage he may go abroad and take up a post as mycologist and plant pathologist. If he has been living in contact with the land his outlook upon the plant industry he has been sent to aid will probably be sound, but if he has not been brought into contact with growing crops, he will be gravely handicapped in dealing with diseases of economic importance. He may be supremely expert in laboratory investigation, but may utterly fail when brought into contact with a practical problem, because a sense of crop values has never been inculcated in him. Cultivators sometimes make the complaint that the remedy is worse than the disease, but where such remedies are suggested, they are always based upon ignorance of crops and their economics. Again as already indicated, the influence of environment as a serious factor in the causation of plant disease is of immense importance, and unless the investigator has his attention fixed upon all aspects of the crop, as well as upon the pathogen, his efforts will often be doomed to failure. I suggest, therefore, that during the later stages of his training, the embryo mycologist be given some familiarity with the growth of crop plants, especially as regards the influence of cultural and climatic

factors upon them, and also as regards crop values. It is not necessary to attend formal classes in agriculture to get the requisite point of view, and in many ways the proper outlook is best inculcated through practical instruction in the field by a competent plant pathologist. It may be thought that I have outlined an ideal impossible of accomplishment; I do not think so, and having had considerable experience in the training of mycologists, I have not suggested more than is actually attainable in practice. I have ventured to place this matter before you, because there is a tendency in some quarters to divorce mycology and plant pathology from botany. That I am sure is a profound mistake, and I trust that any tendency in that direction will be resisted to the uttermost in this country.